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Fatigue Analysis of Girders in a Composite Bridge Using ANSYS

[1]Jayakrishnan. T J, [2]Lekshmi Priya. R

[1]*M Tech Student, Sree Narayana Institute of Technology, Theppupara, Adoor, Kerala*

[2]*Assistant Professor, Department of Civil Engineering, Sree Narayana Institute of Technology, Theppupara, Adoor, Kerala*

Abstract— *Fatigue failure is nowadays an important subject of research in the domain of fracture mechanics. Composite structures have many useful applications in the field of aerospace, civil infrastructure and construction. Steel and composite (steel-concrete) highway bridges are subjected to dynamic actions of variable magnitude due to convoy of vehicles crossing the deck pavement. The main conclusions of this investigation are focused on alerting structural engineers to the possible distortions, associated to the steel and composite bridge's service life when subjected to vehicle's dynamic actions. In this paper, finite element tool ANSYS Workbench is used for the study of seismic behavior of composite bridge*

Keywords—*Bridges, Composite Bridges, Modal Analysis, Fatigue Analysis*

I. INTRODUCTION

Bridges are not simply structures made out of materials, they are parts of life. In many places life would be seriously disrupted, traffic would be paralyzed and business would be terribly affected if the bridges fail functioning. A composite bridge is one whose decking system consists of a concrete slab and moving loads are resisted by the steel girders. It provides an efficient and cost-effective form of bridge construction. In recent days, the common usage of composite construction is meaning steel -concrete construction. Steel concrete composite bridges became commonly used all over the world, because of their aesthetic appearance and economy. Their capability of covering long spans without requiring form work makes them more desirable in metropolitan areas. In addition, there is a significant difference in the weight of steel plate girder bridges and concrete box girder bridges which has an important effect on the seismic design.

Structural fatigue can be defined as the process of accumulation of damage due to application of time varying stress. It can be expected to occur whenever a structure is subjected to time varying loads and in many situations may govern the design. Each time a load cycle is applied, an incremental amount of damage occurs. This damage is cumulative in nature and accumulation continues till the failure occurs. If fatigue cracks are detected early, repair may be possible. The present investigation utilizes techniques for counting stress-cycles and for applying cumulative damage rules combined with S-N curves.

II. FEATURES OF COMPOSITE BRIDGE

A. Modelling and loading of conventional bridge

Two cases are considered. In the first case 5 longitudinal girders are provided at a spacing of 2m c/c distance and in the next case 3 girders are provided at a spacing of 3.75m. Material used are M30 grade concrete and Fe415 grade steel for both cases. Case 1 & 2 is a single span roadway bridge of 25m length. Deck slab is of 9.9m width and 300mm thickness. Footpath of 1.2m is provided on both sides. Composite bridge is modelled as solid 186, solid 187, surf154, targe170, conta174 element in ANSYS Workbench. It is a three dimensional twenty nodded solid element. This solid has the capacity of crushing in compression and cracking in tension. And also it has special features like plasticity, creep, cracking, crushing, large deflection and large strain. Translations are in the nodal X, Y and Z directions. Fig. 1 shows the composite bridges.

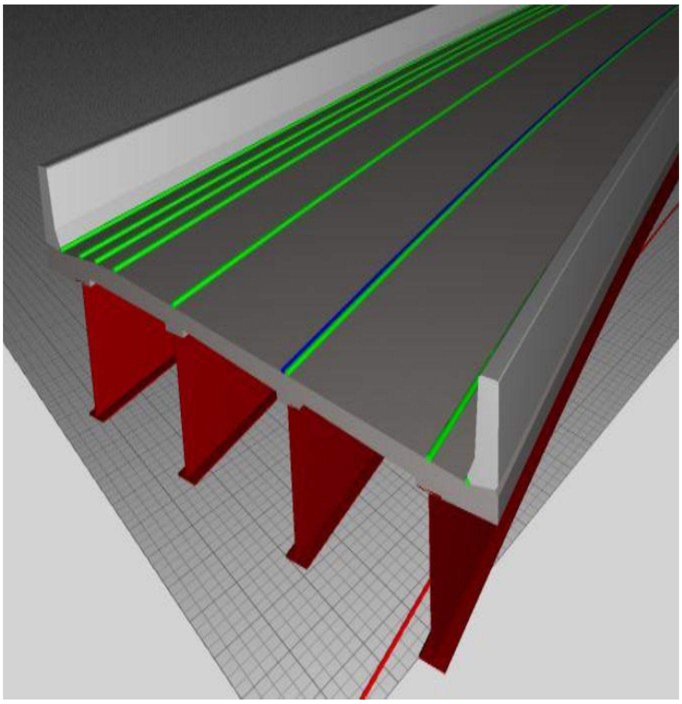

Fig.1. Composite Bridge

III. SOFTWARE USED

A. CATIA V6

CATIA is the world's engineering and design leading software for product 3D CAD design excellence. It is used to design, simulate, analyze, and manufacture products in a variety of industries including aerospace, automotive, consumer goods, and industrial machinery, just to name a few. In this paper, the composite bridge is modelled in CATIA and it is shown in Fig.2

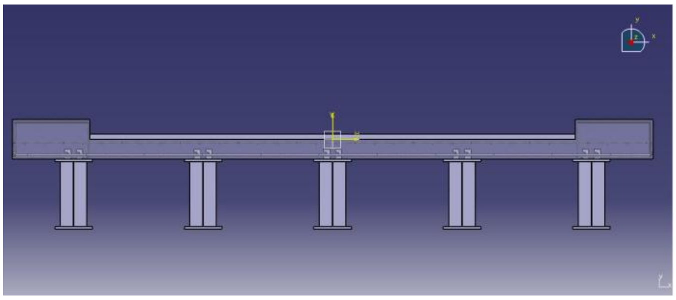

Fig. 2. Bridge modelled in CATIA

B. ANSYS WORKBENCH

The ANSYS Workbench platform is the backbone for delivering a comprehensive and integrated simulation system. Using Workbench for product development simulations will result in higher productivity from integrated applications leveraging common and compatible data models. Workbench gives access to multi physics and systems level insights that could not be attained before. IT organizations realize greater reliability, lower support costs and lower total cost of ownership because our platform addresses the hardware, software and data compatibility problems encountered with using many standalone applications.. In this paper the bridge model is imported to ANSYS Workbench. It is shown in Fig.3. It is a comprehensive finite element analysis (FEA) tool for structural analysis, including linear, nonlinear, dynamic, hydrodynamic and explicit studies. It provides a complete set of elements behavior, material models and equation solvers for a wide range of mechanical design problems.

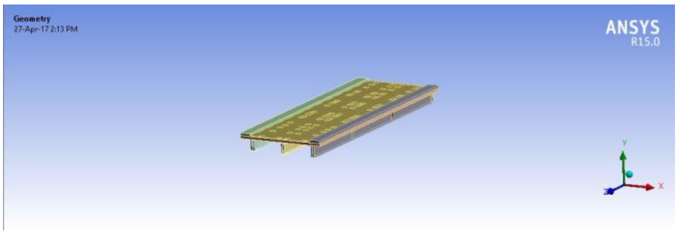

Fig.3. Imported model in ANSYS

IV. FATIGUE ANALYSIS OF COMPOSITE BRIDGE GIRDERS

Fatigue is defined as the loss of resistance of a material with the application of dynamic or repeated loads. The fatigue failure is characterized by the loss of strength due to the crack growth. Fatigue is a progressive deterioration of a structure by crack growth, due to a series of stress variations (cycles) resulting from the application of repeated loads, such as induced in bridge components under traffic loads and heavy vehicle crossings.

A. Material Properties

The Engineering Data Manager provides a powerful tool for defining, organizing, and storing material properties. Material properties of structural steel are already available in ANSYS Engineering data. Material properties of steel, concrete and bitumen are as shown in Table 1.

Table 1. Material Properties

SL.NO	Material	Young's modulus (pa)	Poisson's ratio	Density (Kg/m^3)
1	Concrete	4.5E+10	0.18	2500
2	Steel	2E+11	0.3	7850
3	Bitumen	6400	0.4	2243

B. Section Properties

The thickness provided for wearing coat is 80mm. Based on the codal provisions, girder dimensions of the flange plate are 580mm x 40mm, web plate are 1000mm x 10mm for case1, and girder dimensions of flange plate are 600mm x 40mm, web plate are 1200mm x 30mm for case 2.

C. Meshing

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient multi physics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time we have to wait for mesh generation. A finer mesh produces more precise answers but also increases CPU time and memory requirements. In this analysis, suitable numbers of elements were carefully chosen for the models based on convergence studies in order to obtain accurate results without excessive use of computer time. Fig. 4 and 5 show the meshing of model.

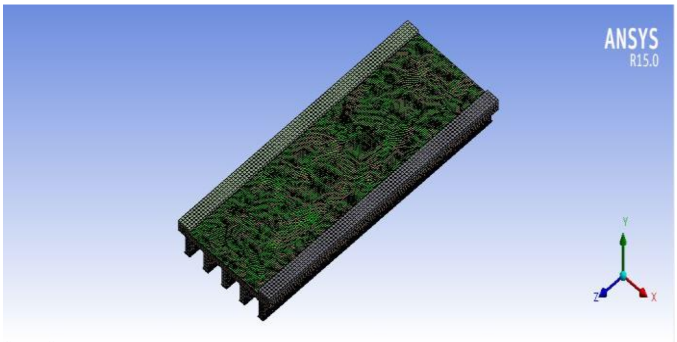

Fig. 4. Meshed Model of case1

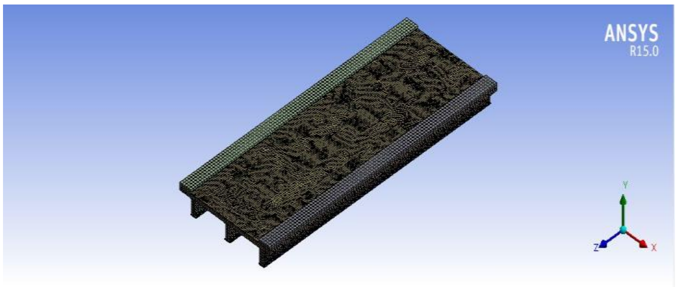

Fig. 5. Meshed Model of case2

D. Results and Conclusions

Fatigue analysis is done and safety factor and life of each bridge are determined. Figure 6 and 7 show the safety factor of bridges in each cases.

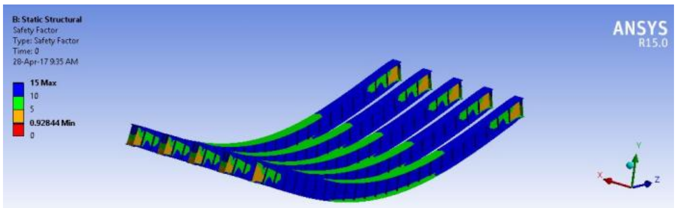

Fig. 6. Safety Factor of case1

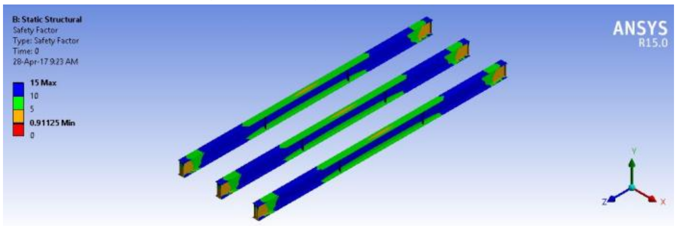

Fig. 7. Safety Factor of case2

Fig. 8 and 9 show the fatigue life of 5 girder and 3 girder bridges.

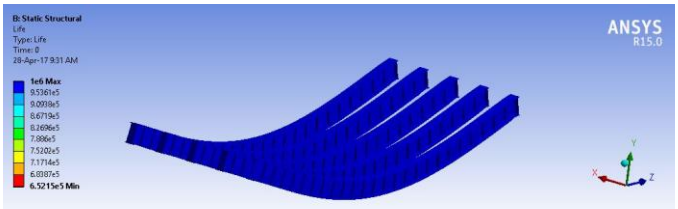

Fig. 8. Fatigue Life of of case1

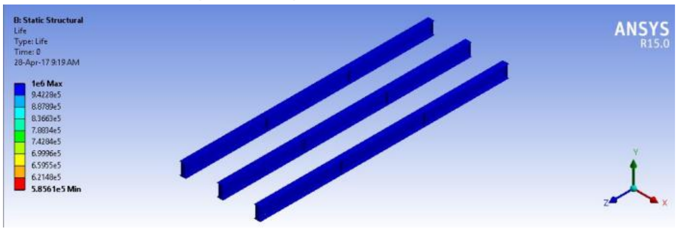

Fig. 9. Fatigue life of case2

After Fatigue analysis, safety factor and fatigue life values of the two bridge structures are compared and as shown in Table 2.

Table 2. Comparison of Results

BRIDGE WITH 5 GIRDERS		**BRIDGE WITH 3 GIRDERS**	
Safety Factor	**Fatigue Life (Cycle)**	**Safety Factor**	**Fatigue Life (Cycle)**
0.9118	$1*10^6$	0.92	$1*10^6$

V. CONCLUSIONS

From the Fatigue Analysis, it is found that both the bridges have approximately same safety factor and fatigue life.

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